Clouds in the Met Office models

Can ARM CMWG help with our future development?

ARM cloud modelling and aerosol meeting

Wed Sep 30th

Jon Petch

Peter Hill, James Manners, Cyril Morcrette

People

- Radiation
  - James Manners
  - Peter Hill
- Clouds
  - Cyril Morcrette

- Microphysics (see Paul and Adrian's talks)
  - Paul Field, Adrian Hill and Jonathan Wilkinson

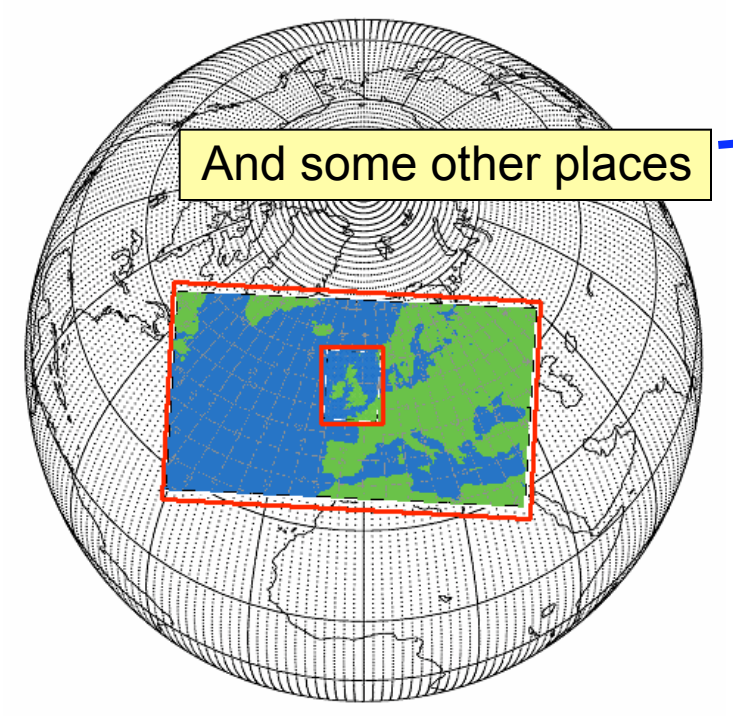
Contents

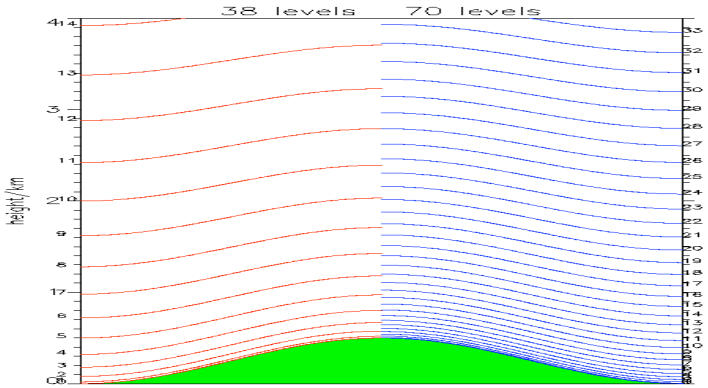
- What we do with our model
  - weather through to climate
- Radiation (cloudy)
  - a cloud generator and McICA
- Some longer term plans
  - clouds, radiation, (microphysics & aerosols)
- Cloud scheme diagnosis
  - the sick plots
- How ARM CMWG might help

Current atmospheric model configurations

What do our parametrizations need to do?

The operational forecast models





NWP (horizontal grid lengths)

- Global: 40 km (25km Dec)
- Atlantic/Europe: 12 km
- UK: 1.5 km

Also various ensembles (25ish) at a reduced resolution

NWP (levels)

- Global: 70
- Atlantic/Europe: 70
- UK: 70 (might go to 110)

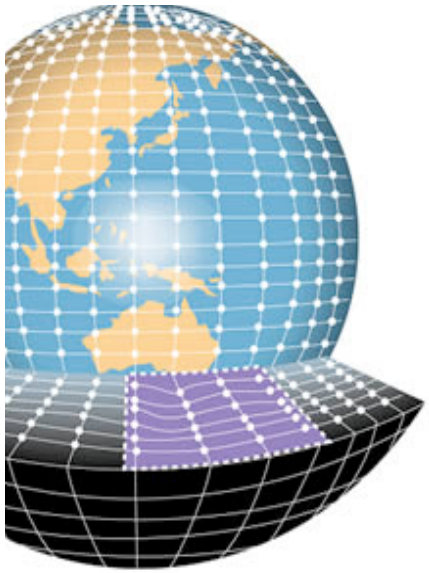
Longer time scales

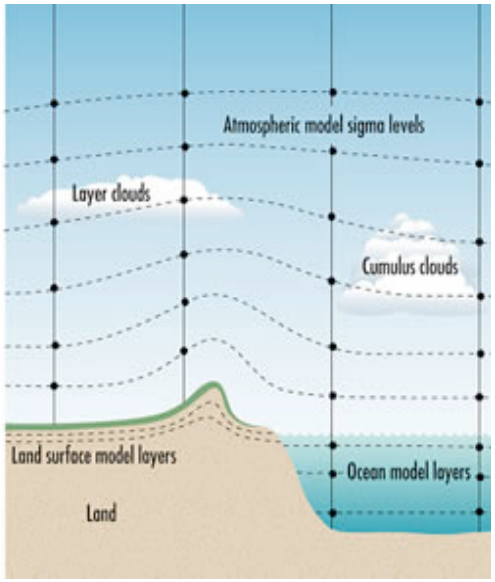
Horizontal resolution

- Climate (global): **60** - 140 km
- Seasonal (global) **120 km**
  (perturbed physics and new I.C run every 2 days)
- 15 days: **90 km** (soon 40 km)
- Regional climate 12 - 30 km

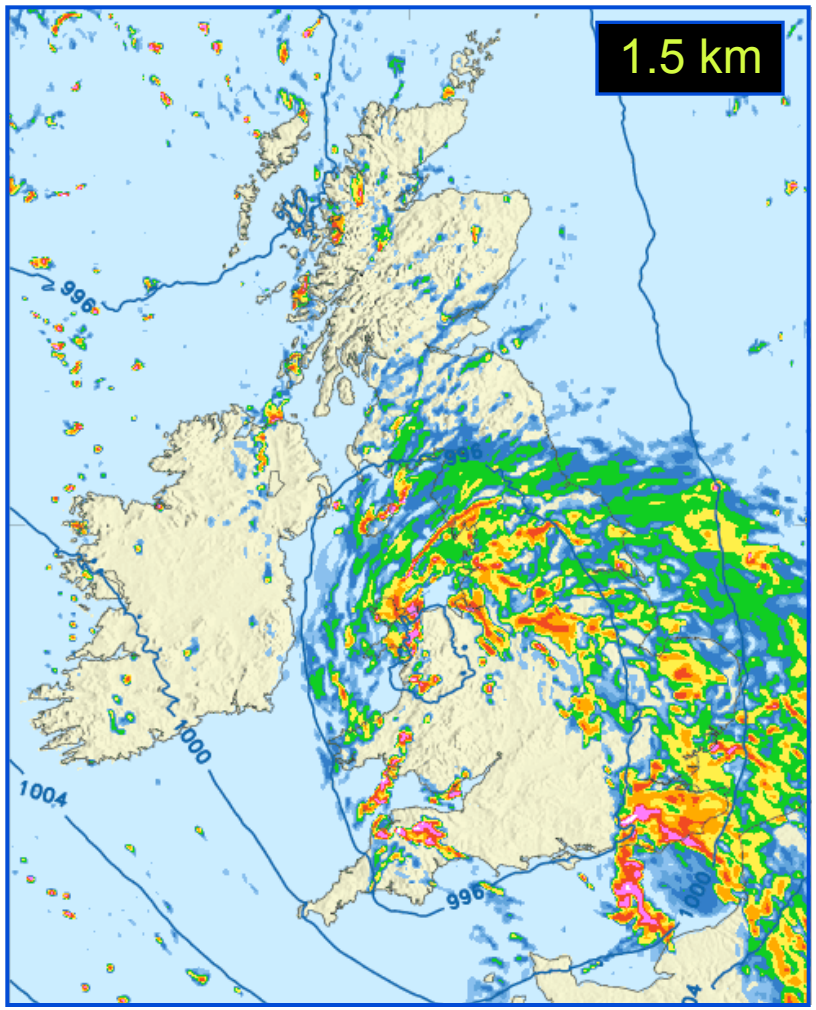
Vertical levels

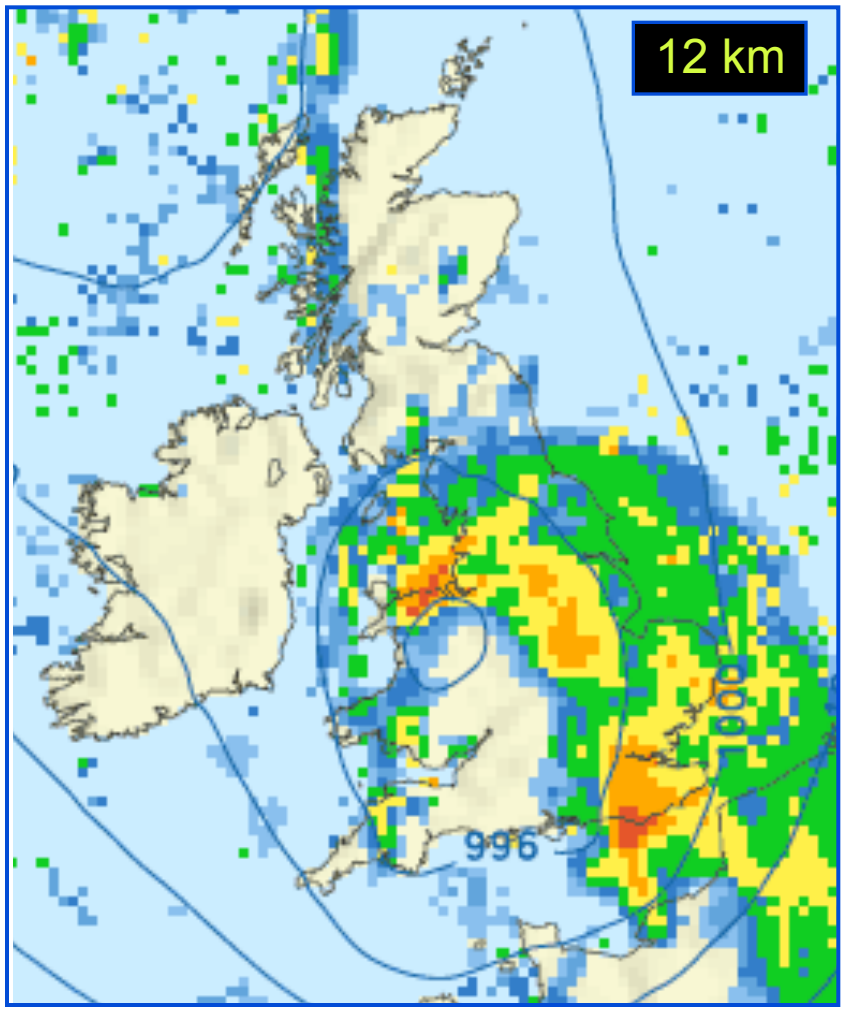
- 63-80 typically (same res in troposphere)





T+21: 9pm 2 Sep 2009
UKV & NAE





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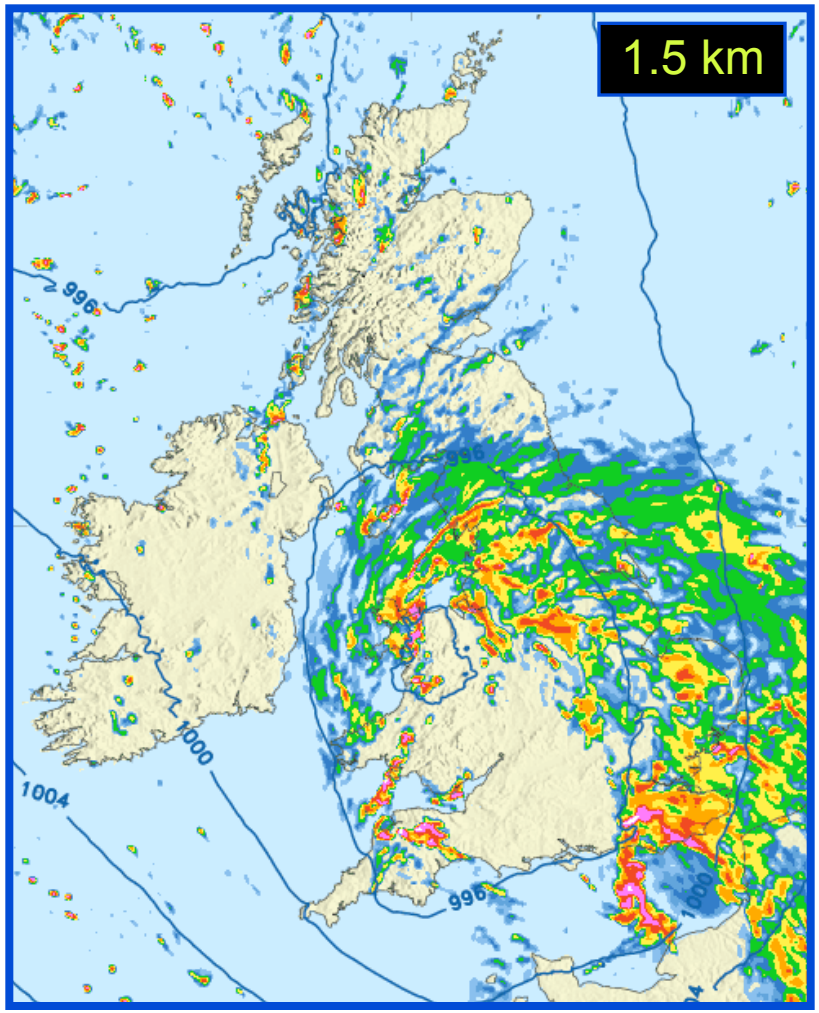
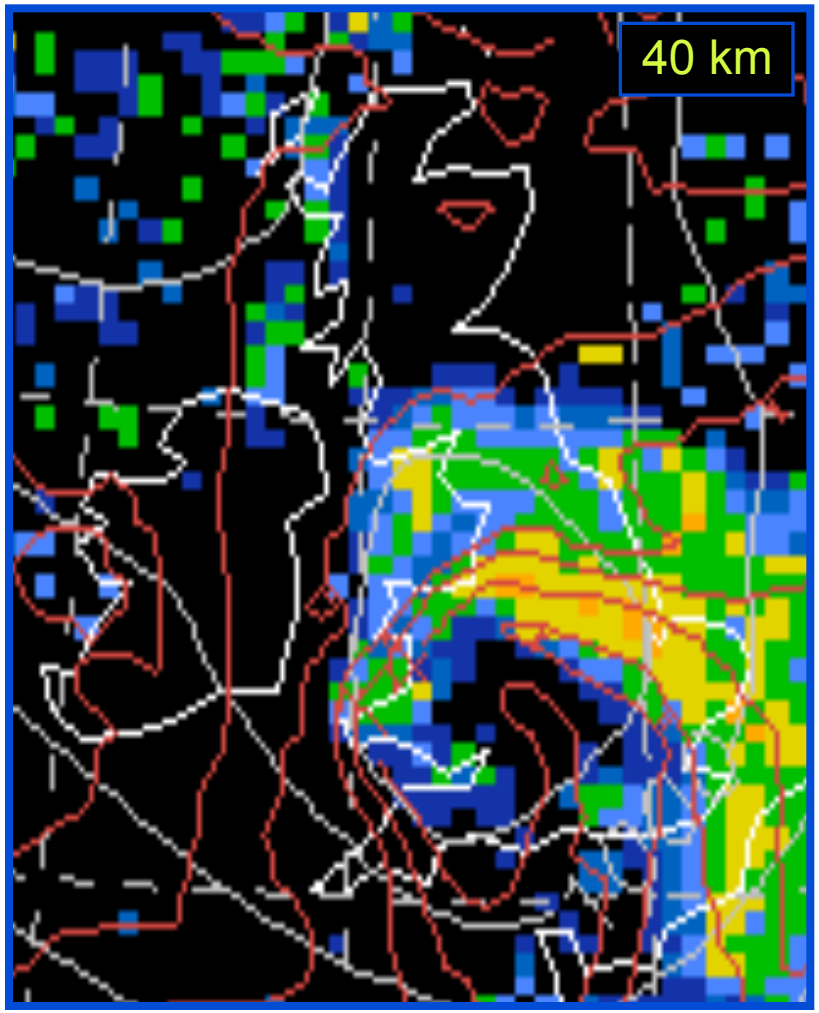
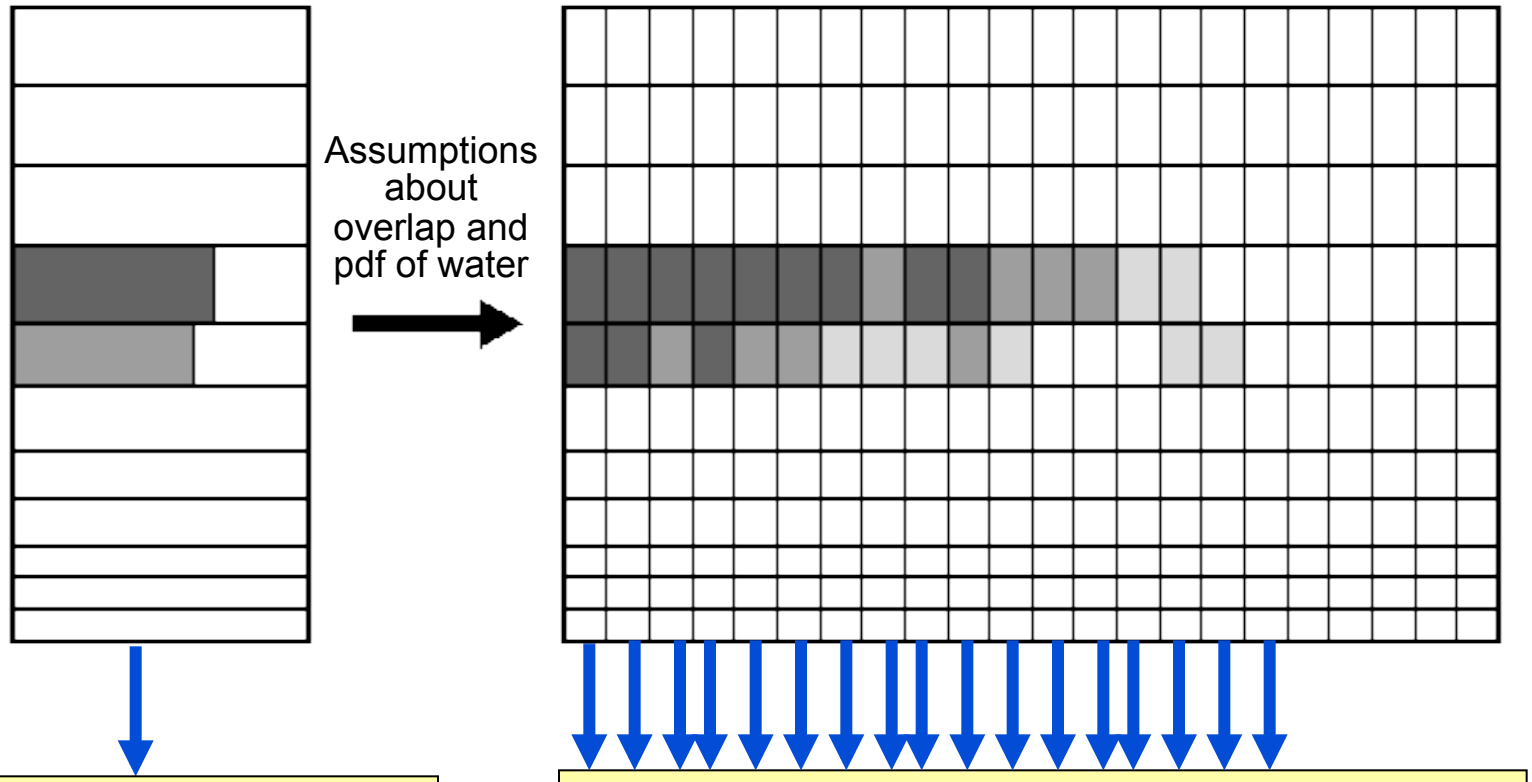




Radiation: cloud generator and McICA

McICA & generated cloud



Plain parallel radiation

Assumptions about overlap

Possible fudges about inhomogeneity (e.g.0.7)

IPA: Radiation on all columns

McICA: Sample columns with "random" k-terms

McICA & generated cloud

- Introduction of McICA method:

  Pincus, Barker & Morcrette 2003 JGR, **108,** *4376*

- A simple cloud generator:

  Raisanen et al. 2004 QJRMS, **130,** *2047*

- Effect of generated cloud and McICA noise in GCMs:

NCAR CAM: Raisanen et al. 2005 J. Climate, **18,** *4715*

GFDL-AM2: Pincus et al. 2006 MWR, **134,** *3644*

ECHAM5-FMI: Raisanen et al. 2008 QJRMS, **134,** *481*

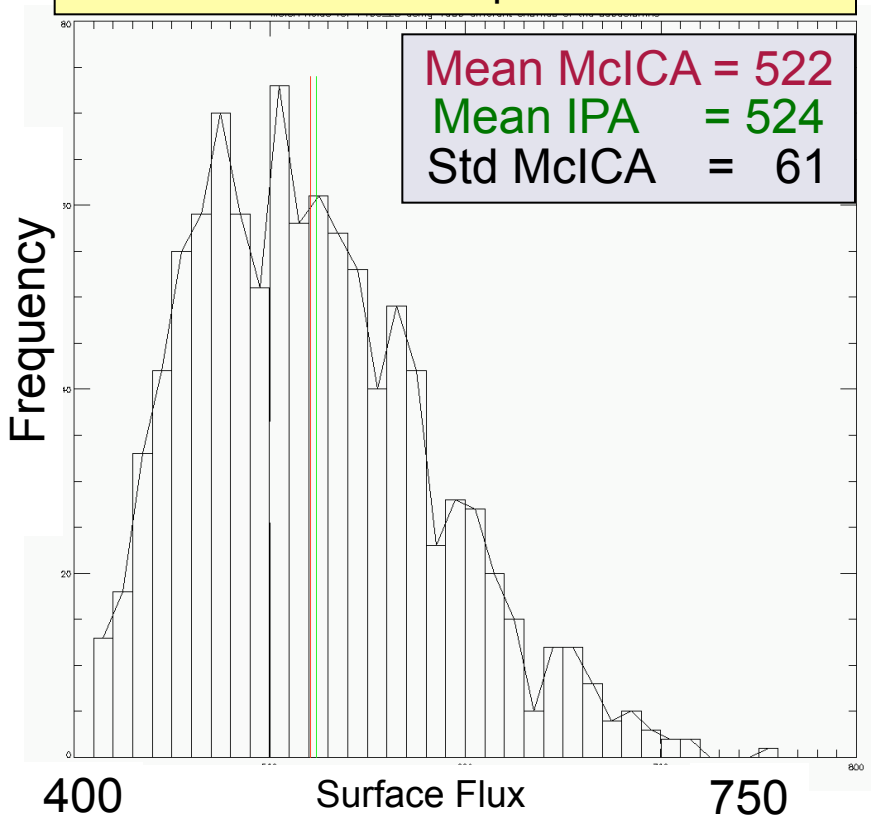
CCCma/GEM: Barker et al. 2008 QJRMS, **134,** *1463*

ECMWF: Morcrette et al. 2008 MWR, **136,** *4760*

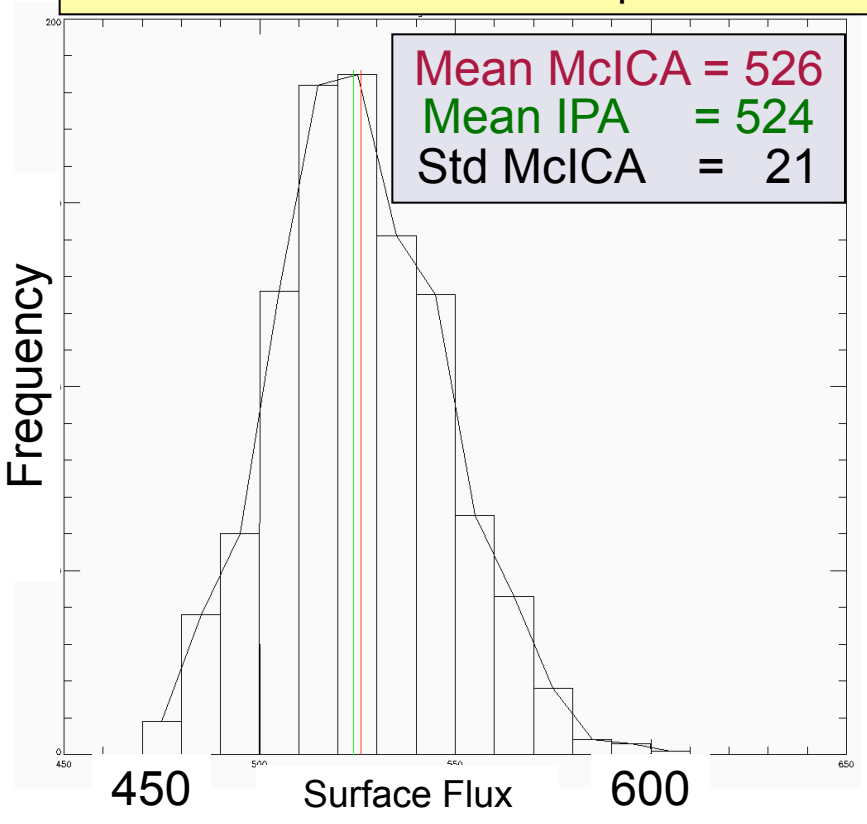
Sampling generated cloud using McICA

Reducing the noise in McICA - choosing our k-terms carefully

1 sub-column per k-term



5 sub-columns for 4 most important k-terms



Surface shortwave fluxes from 1000 runs of the same cloud scene

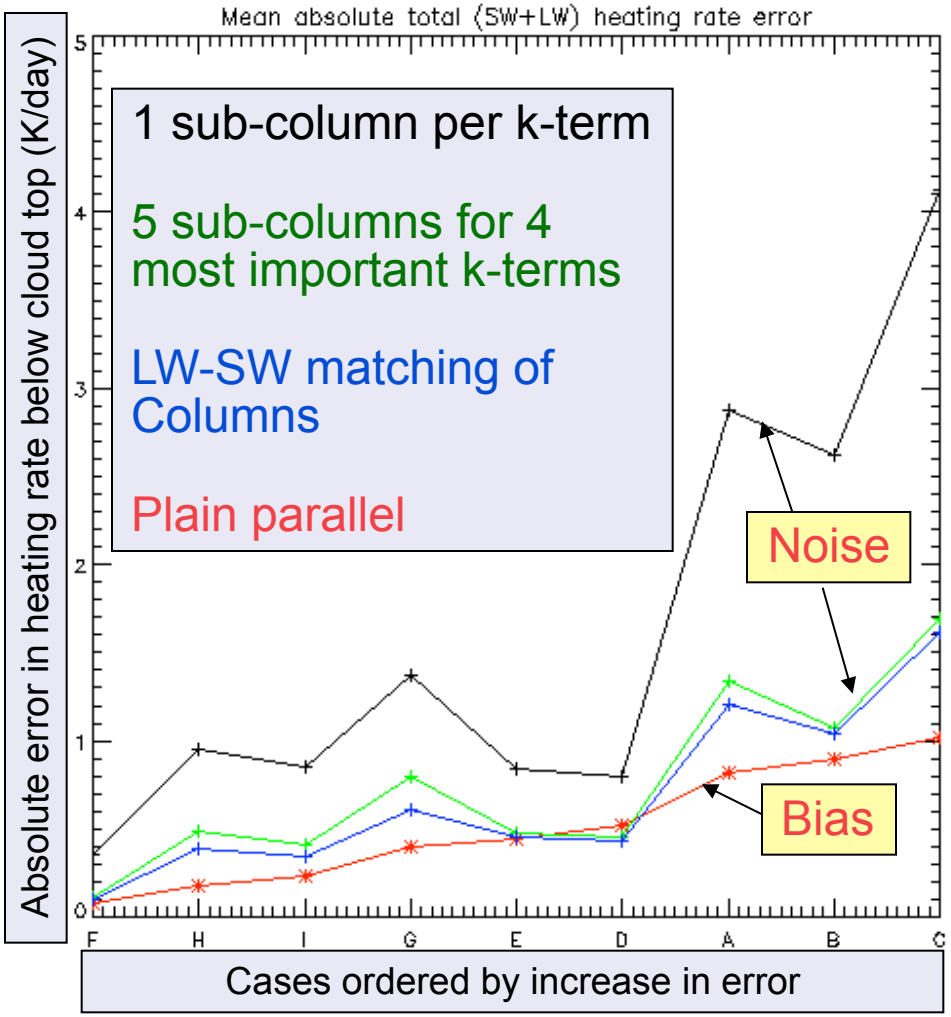
Minimising McICA noise – ensuring the key k-terms in the LW and SW 'see' similar clouds

Clouds generally cause heating in the SW and cooling in the LW.

When the plane-parallel total (SW+LW) effect is calculated, errors can cancel.

This cancellation does not necessarily occur for McICA if the SW and LW 'see' independent random columns.

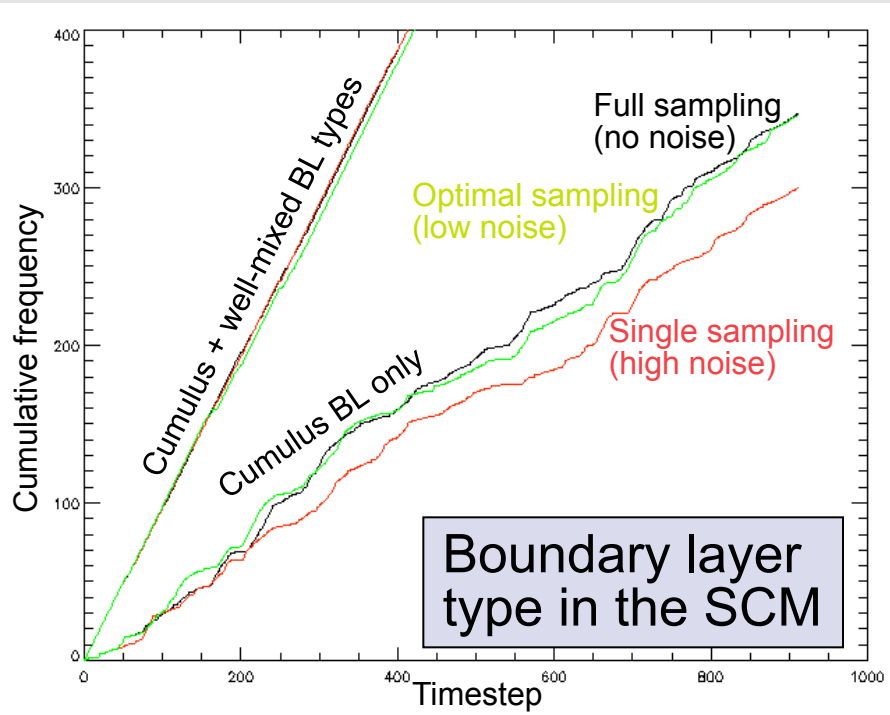
A free tweak is to match choice of columns in LW and SW for main terms.



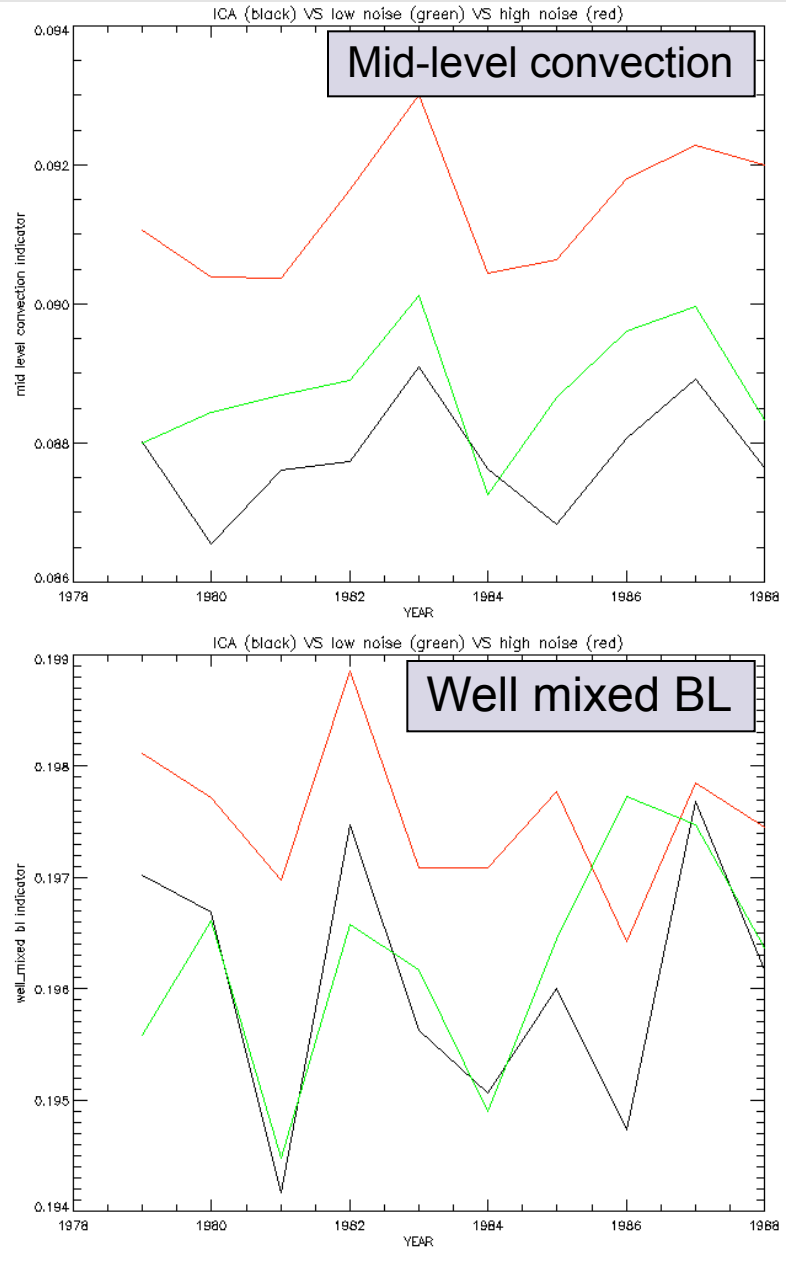
McICA noise in the climate model

Noise causes a change in some convection and BL type indicators

SCM – TOGA-COARE



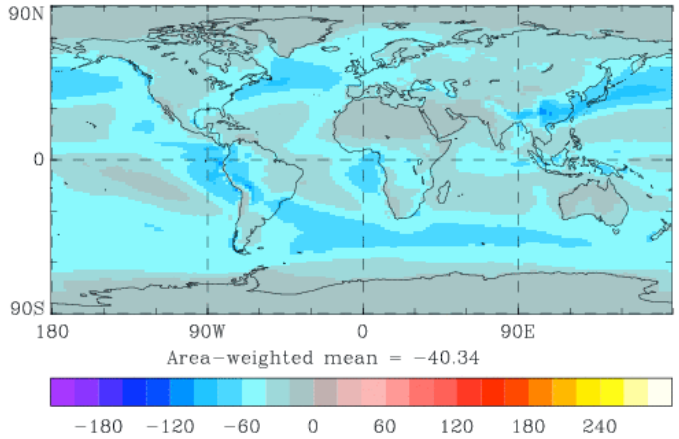
10 year climate runs



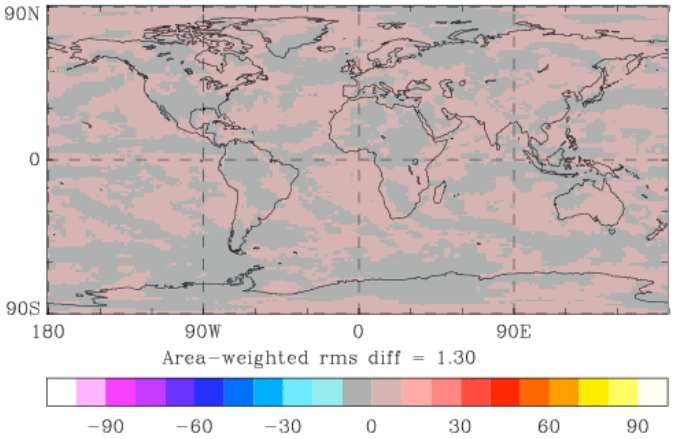
The cloud generator would need regional variations to hit observed biases

tuned overlap and variability assumptions

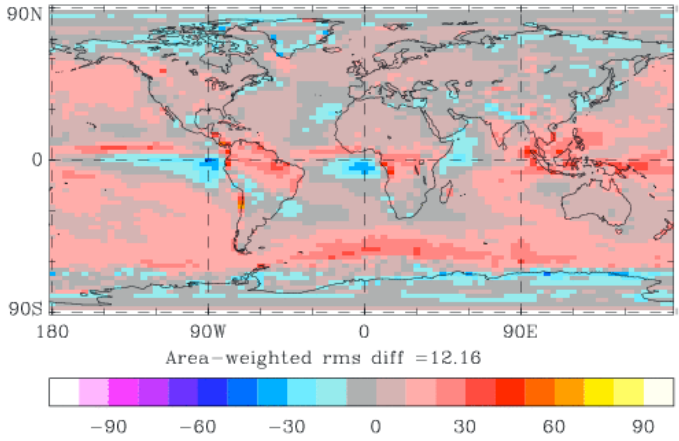
McICA



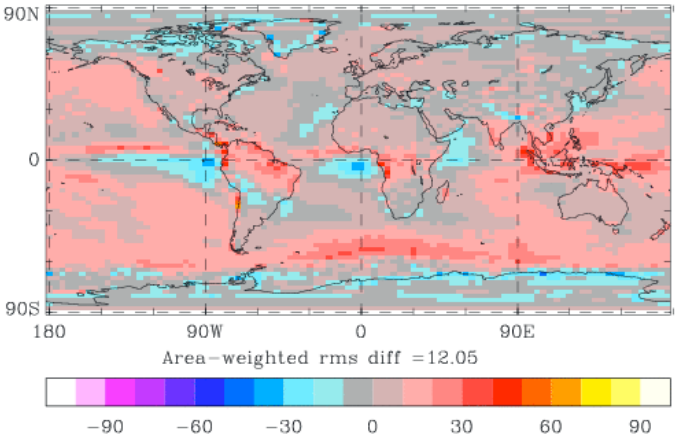
McICA - Control



McICA - CERES

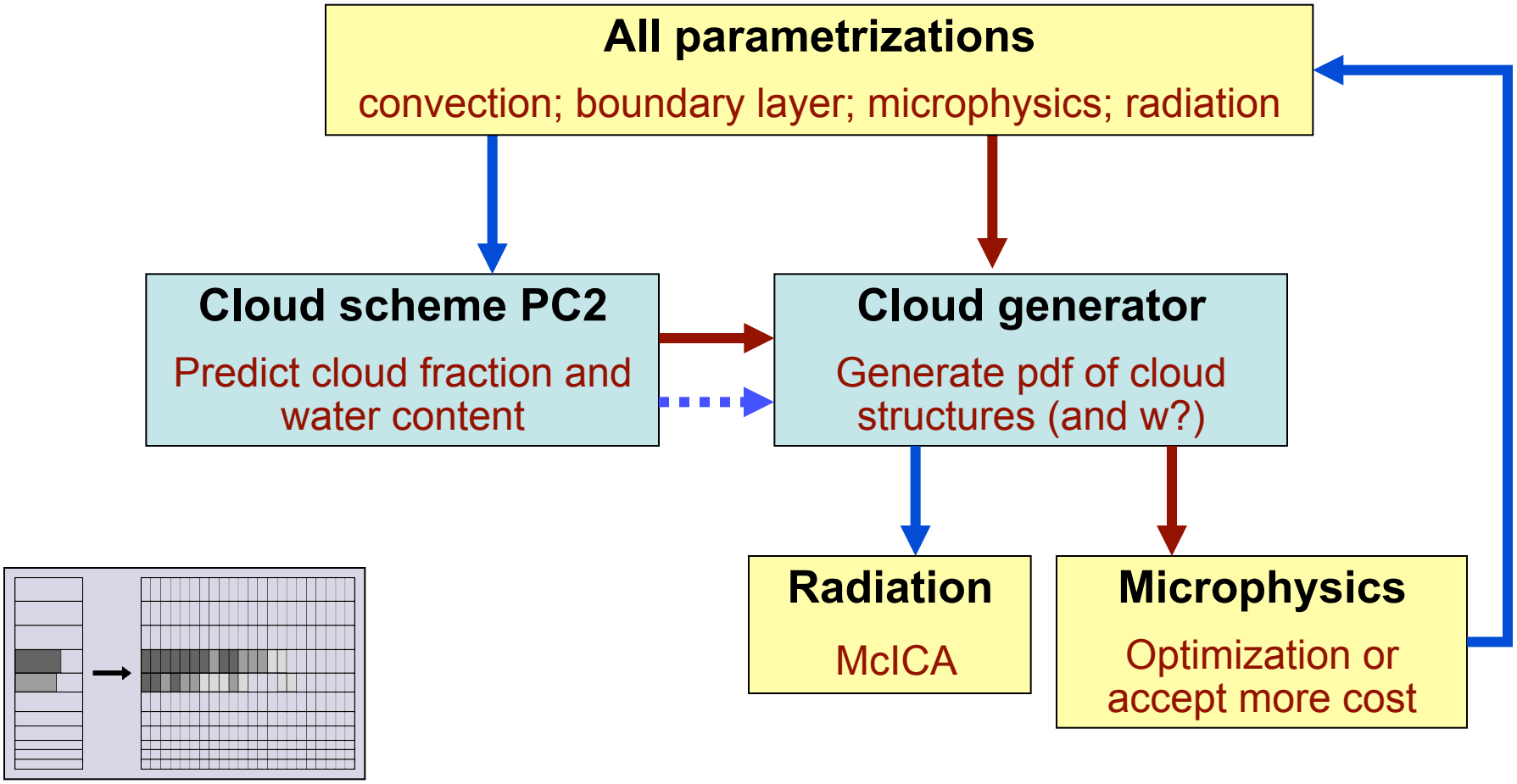


Control - CERES

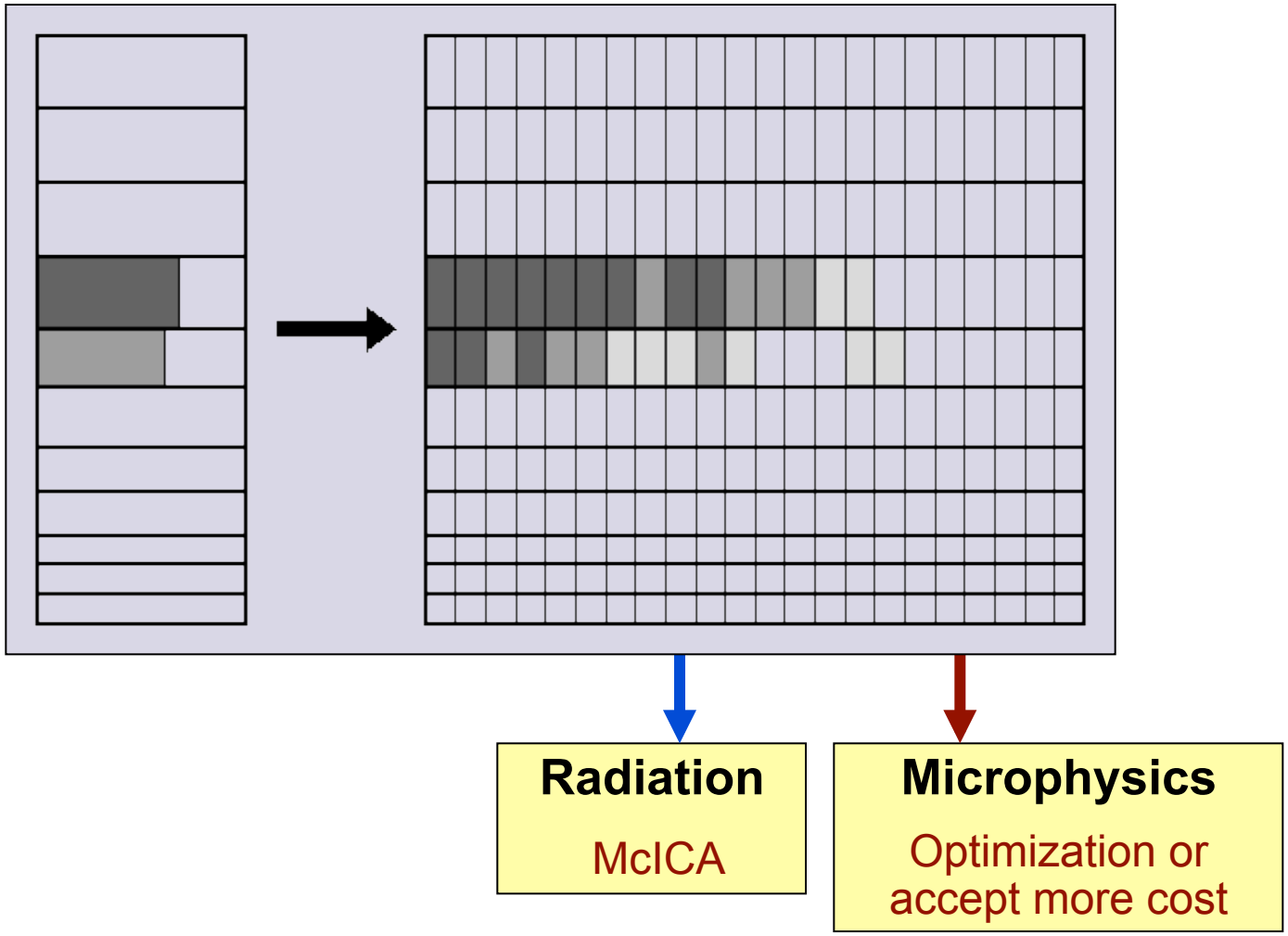


SW cloud forcing from 10 year AMIP type run

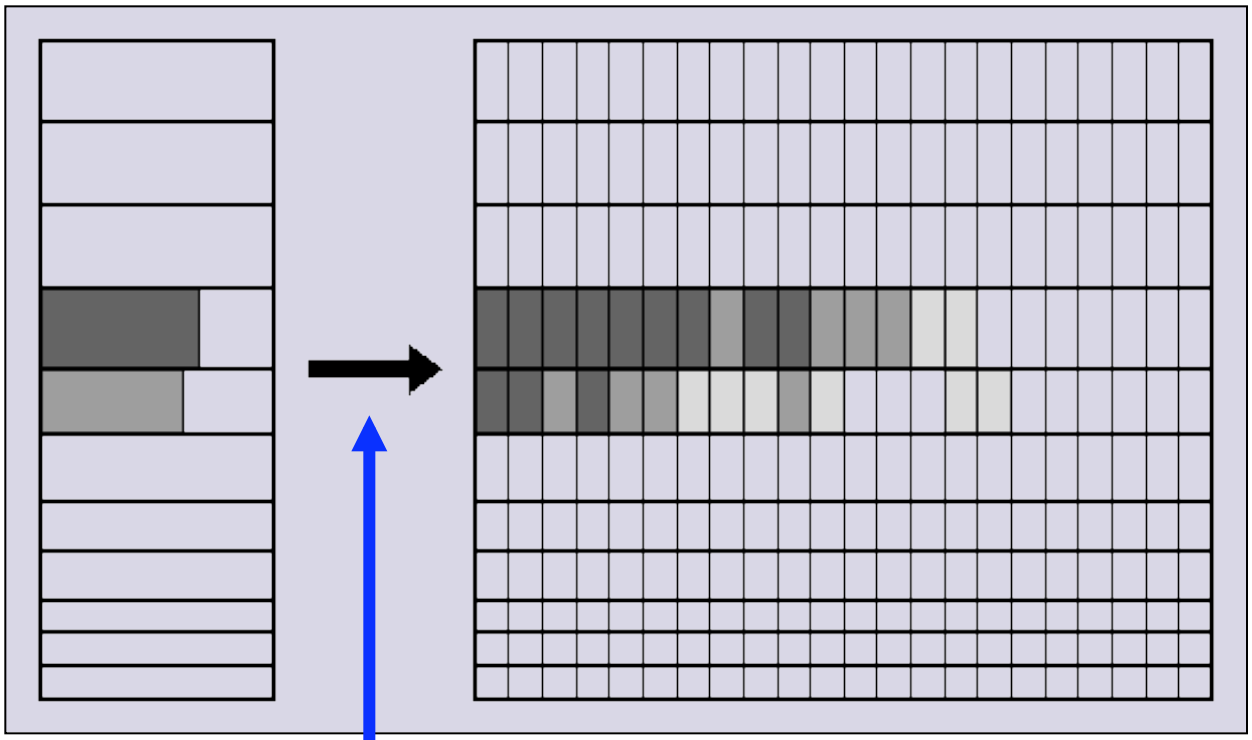
Strategy for clouds – radiation and microphysics



Strategy for clouds – radiation and microphysics



Strategy for clouds – radiation and microphysics



Cloud scheme PC2

And/or other info from all physics schemes

The cloud scheme

PC2

QUARTERLY JOURNAL OF THE ROYAL METEOROLOGICAL SOCIETY
Q. J. R. Meteorol. Soc. **134**: 2093–2107 (2008)
Published online 12 November 2008 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/qj.333

RMetS
Royal Meteorological Society

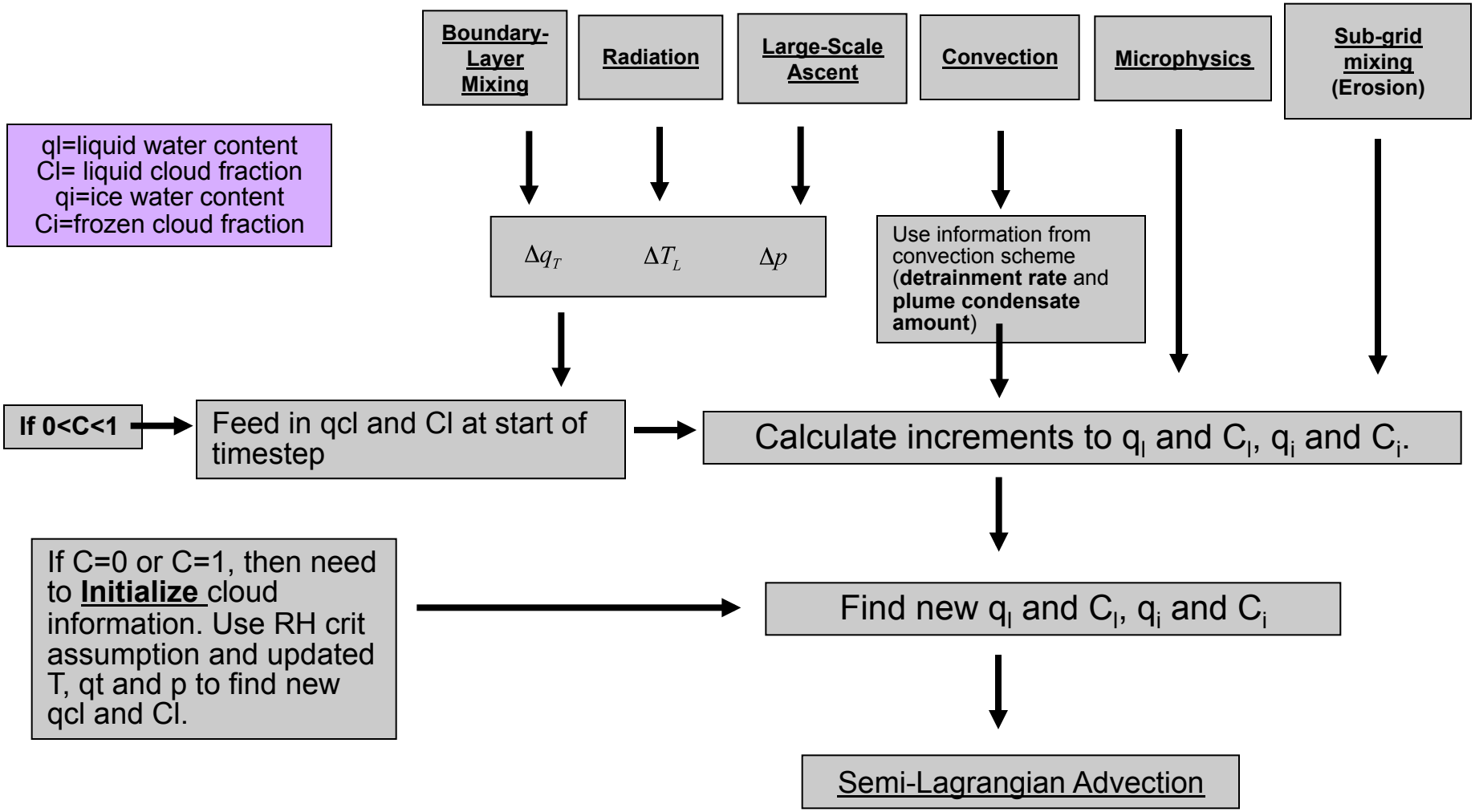
PC2: A prognostic cloud fraction and condensation scheme. I: Scheme description

Damian R. Wilson, Andrew C. Bushell, Amanda M. Kerr-Munslow,
Jeremy D. Price and Cyril J. Morcrette*
Met Office, Exeter, UK.

$$\Delta Cf = \sum_{i=1}^{N \text{ processes}} \Delta Cf_i \qquad \Delta ql = \sum_{i=1}^{N \text{ processes}} \Delta ql_i$$

PC2: A Beginner's Guide

(Prognostic Cloud, Prognostic Condensate)

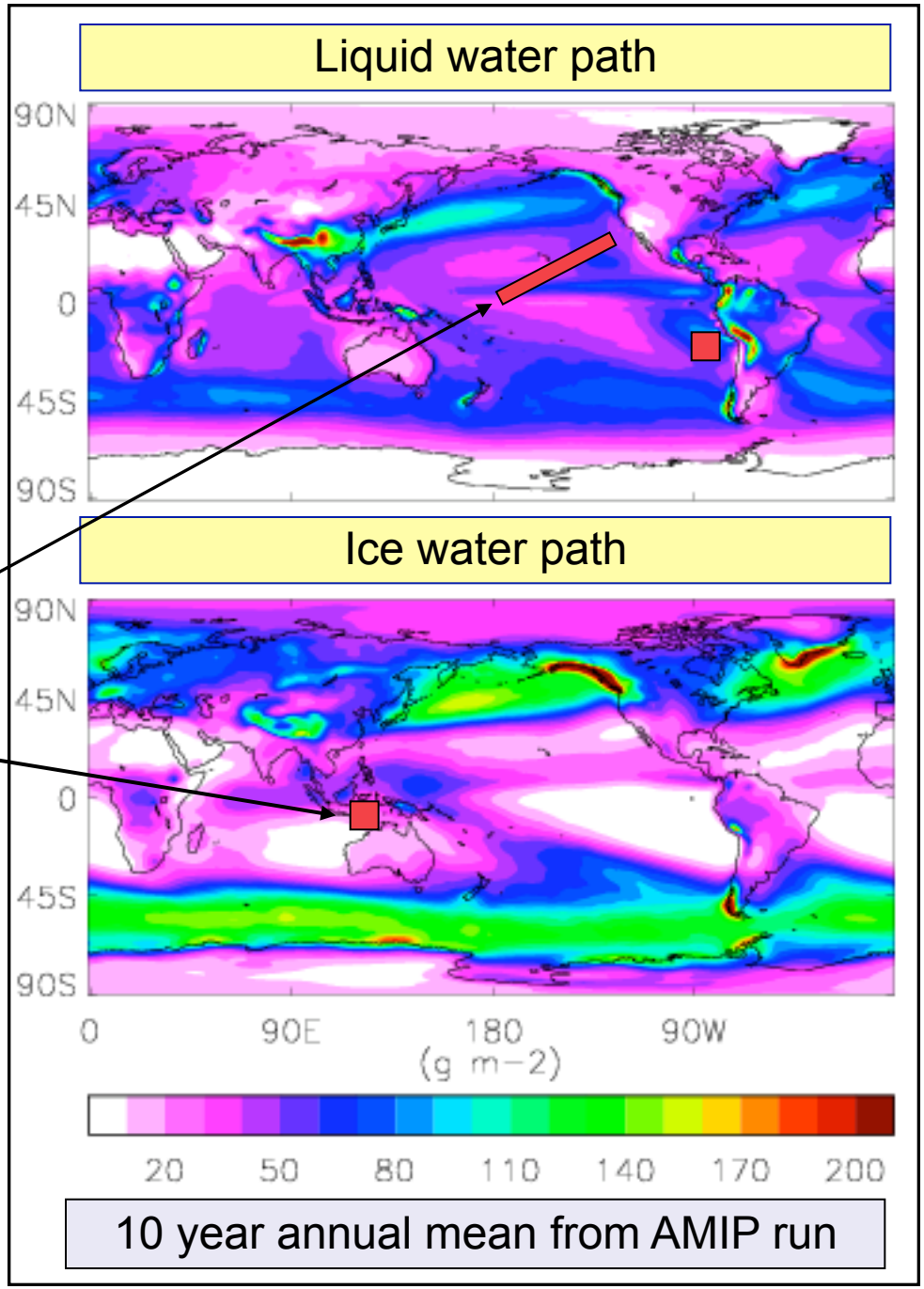


Cyril Morcrette

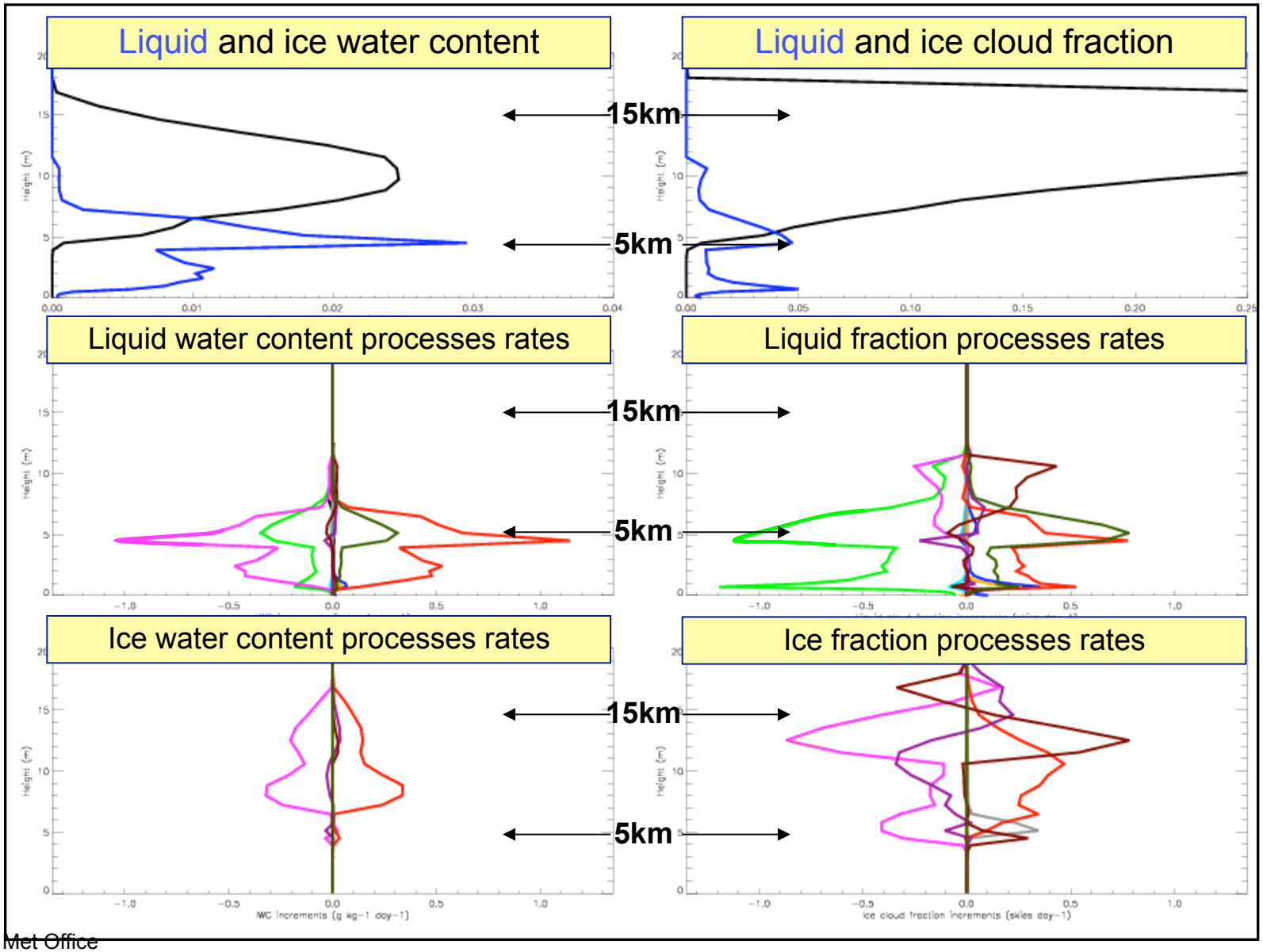
What are the processes which lead to our cloud water contents?

With PC2 we can answer this question:

- **Profiles**
- Cross sections
- **Global means**
- Global maps
- **Sick maps**

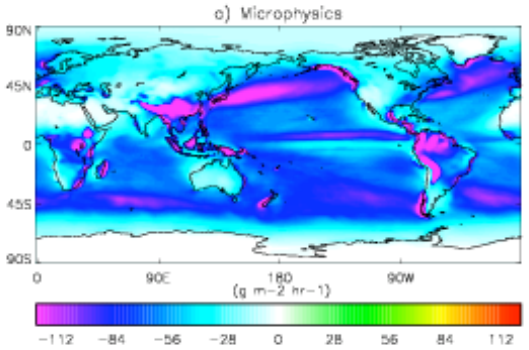


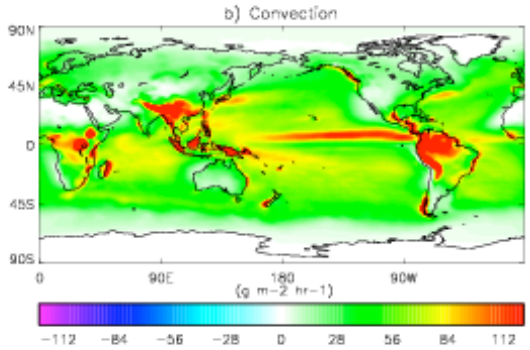
Profiles: Tropical Warm Pool
TWP-ICE region for Dec-Jan-Feb

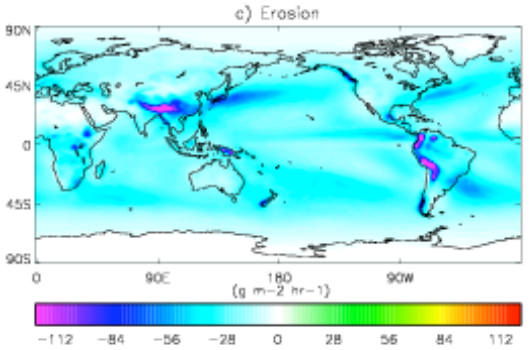


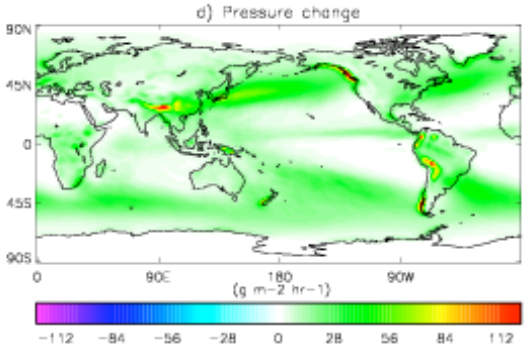
Shortwave
Longwave
Boundary-layer
Erosion
Microphysics
Convection
Advection
Initialization
Pressure change
Total

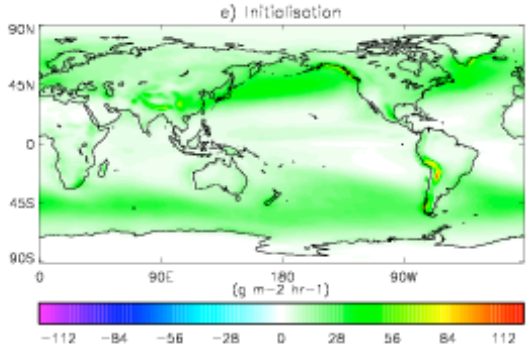
Vertically integrated process rates

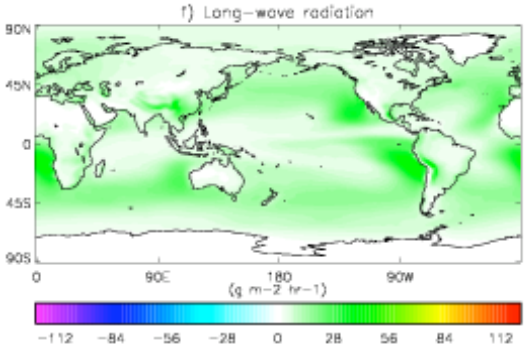


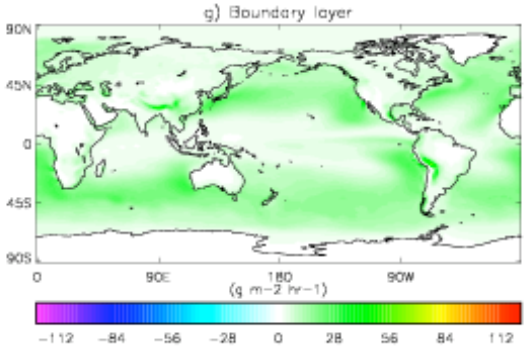


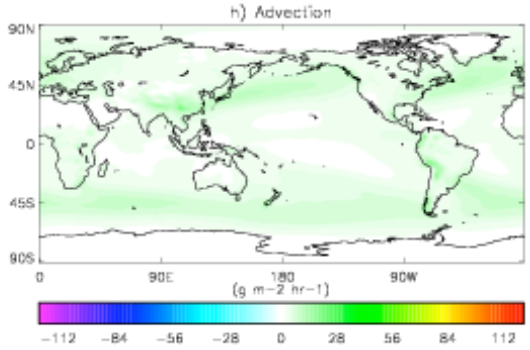


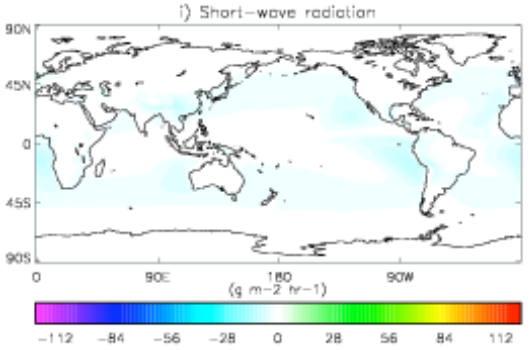






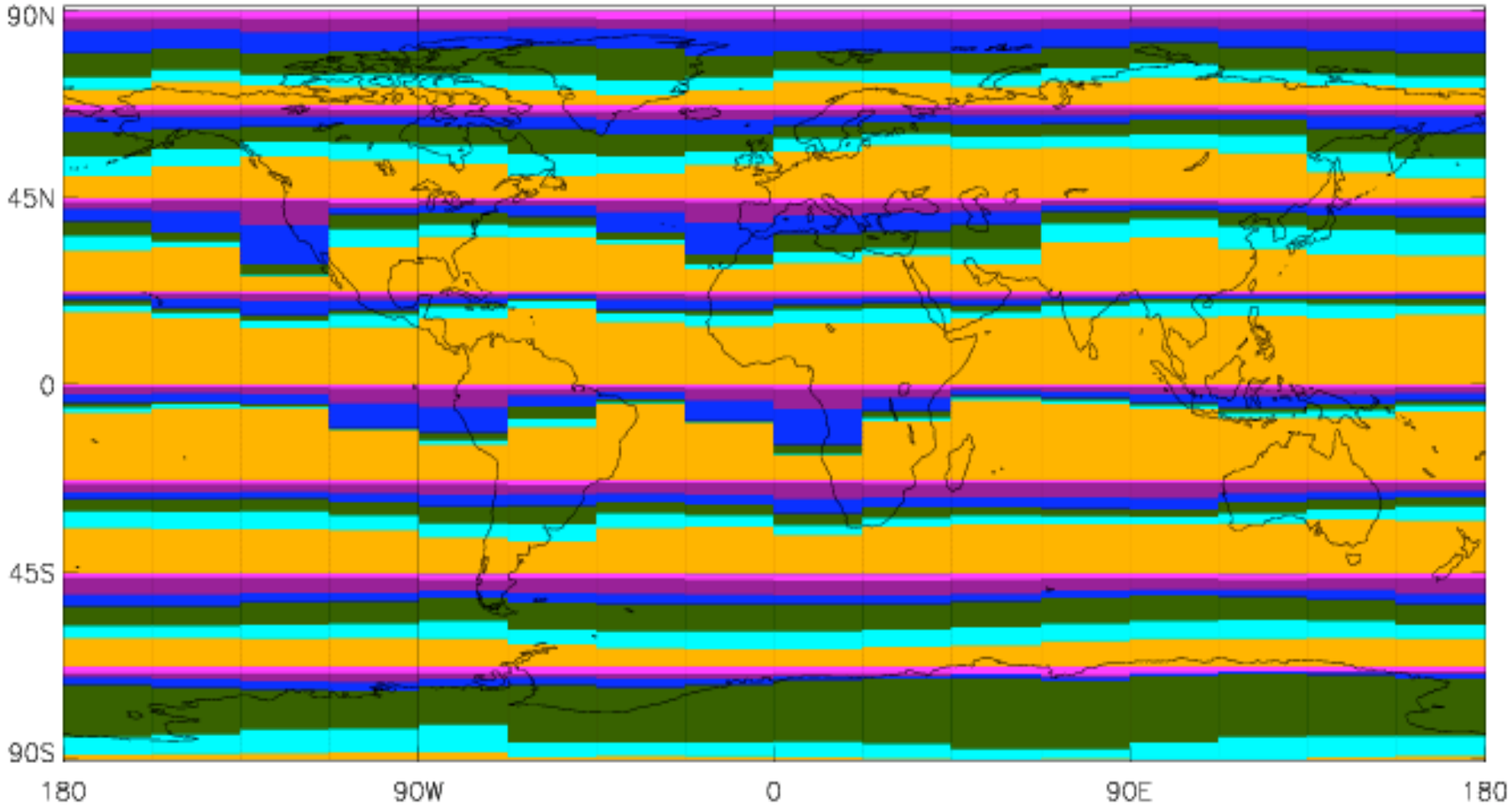






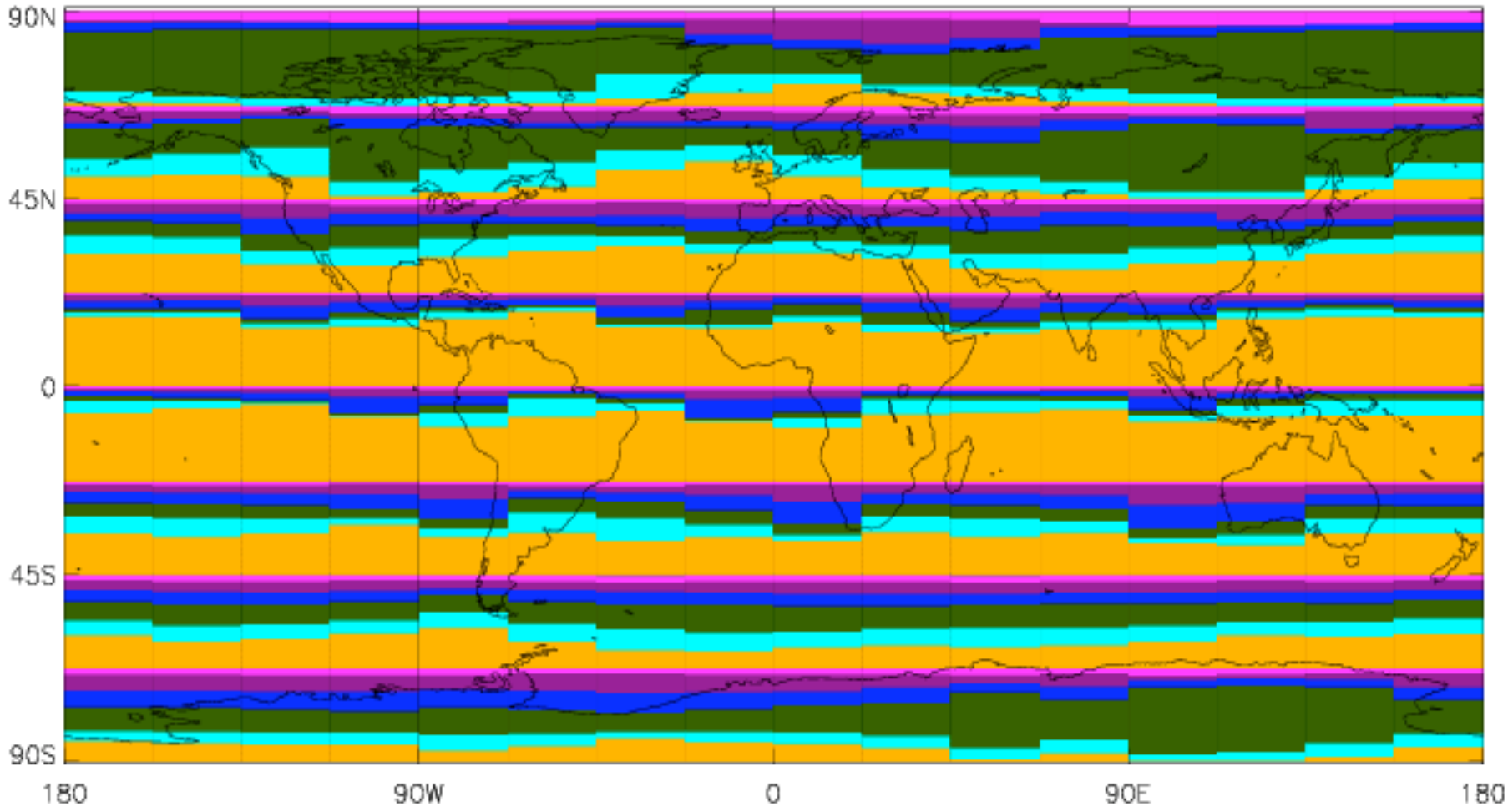
JJA: Proportion of LWP increment from each source

Convection
Pressure change
Initialization
Long-wave
Boundary-layer
Advection
Numerical checks



DJF: Proportion of LWP increment from each source

Convection
Pressure change
Initialization
Long-wave
Boundary-layer
Advection
Numerical checks



Summary/ARM help

Summary

- We plan to make the make use of the cloud scheme terms and other physics in the cloud generator as well as in the development of PC2 itself
- We plan to try microphysics on the generated cloud

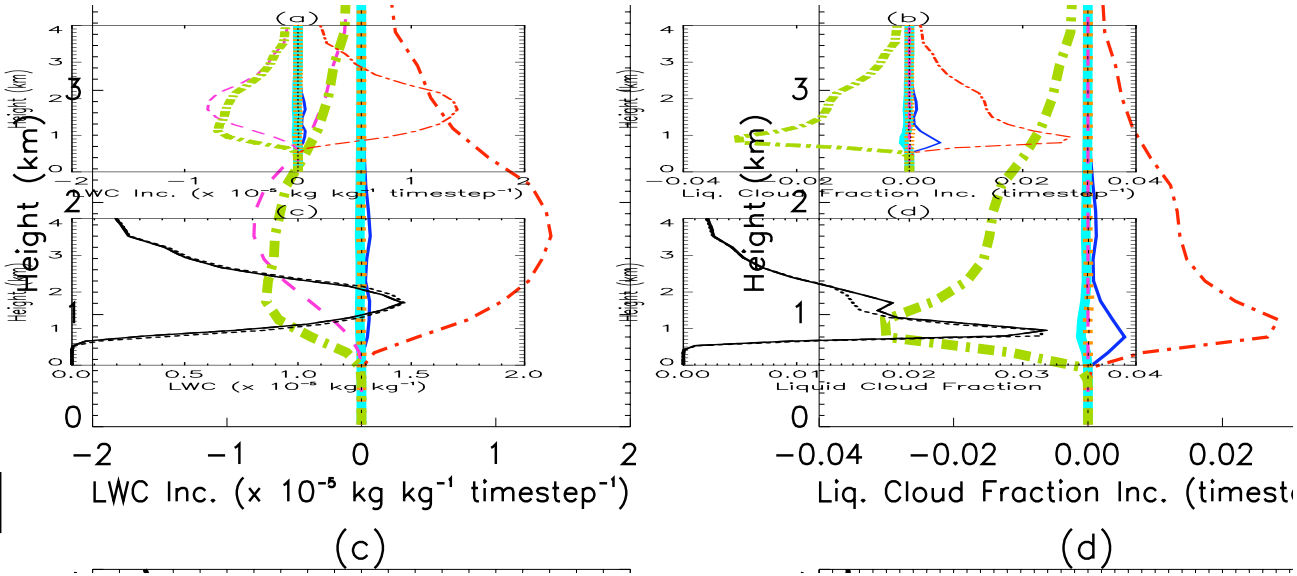
ARM help…

- Collaboration on work to evaluate the process rates in CRM/LES?
- Evaluation of process rates from observations???

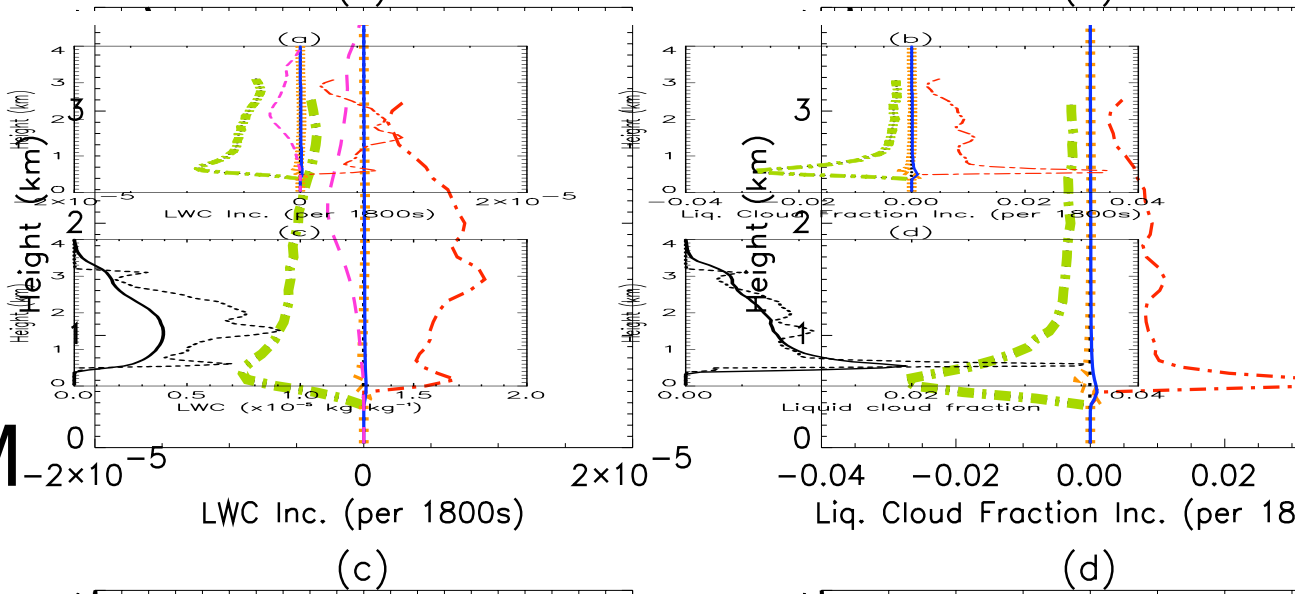
PC2 increment analysis for RICO

Convective detrainment
Erosion
Microphysics
LW rad
SW rad
BL turbulence
Dynamics

UM



LEM



The end

Aerosol schemes in the UM

The UM currently includes a choice of two different aerosol schemes:

- **CLASSIC**
  - "First generation" scheme, developed over the last 15 years. Models aerosol mass only, with fixed size and composition.
- **UKCA-MODE**
  - Replacement scheme under development in collaboration with the University of Leeds. Models aerosol mass and number, with variable size and composition.

Aerosol species included

- Ammonium sulphate (Sources: anthro & natural SO_2, DMS)
- Ammonium nitrate (Sources: anthro & natural NH_3, HNO_3)
- Black carbon (Sources: biomass burning, fossil fuels and biofuels)
- Primary & Secondary Organic carbon (Sources: as BC, plus terpenes)
- Mineral dust
- Sea-salt

Aerosol representation in CLASSIC

- **Prognostic**:
  - Sulphate (3 log-normal modes)
  - Nitrate (2 log-normal modes)
  - Biomass-burning BC/OC (3 log-normal modes)
  - Fossil & bio-fuel BC (3 log-normal modes)
  - Fossil & bio-fuel OC (3 log-normal modes)
  - Mineral dust (6 size sections)
- **Diagnostic**:
  - Sea-salt: $f(u_{10})$ (2 log-normal modes)
- **Climatology**:
  - Secondary OC (1 log-normal mode)

Modelled as an *external* mixture

Aerosol representation in UKCA-MODE

Mode name	Size range	Composition	Soluble?
nucl-sol	r < 5 nm	SU	Yes
Aitken-sol	5 < r < 50 nm	SU, BC, OC	Yes
accum-sol	50 nm < r < 500 nm	SU, BC, OC, SS, DU	Yes
coarse-sol	r > 500 nm	SU, BC, OC, SS, DU	Yes
Aitken-ins	5 < r < 50 nm	BC, OC	No
accum-ins	50 nm < r < 500 nm	DU	No
coarse-ins	r > 500 nm	DU	No

(Nitrate not yet implemented)

Modelled as *internally mixed* modes

Aerosol effects in the UM

- **Direct effect** (and therefore **semi-direct effect**) of all aerosols
- **1st** (albedo) and **2nd** (precip. efficiency) **indirect effects** on liquid water clouds (soluble aerosols only)
- No effects on ice clouds included

Parameterization of droplet number concentration

- **CLASSIC**

  Empirical scheme based purely on aerosol mass, treated as an *external mixture*:

  $N_d = f$(accumulation modes of SO_4, NO_3, OC & SS)

  Cannot distinguish between different aerosol types.

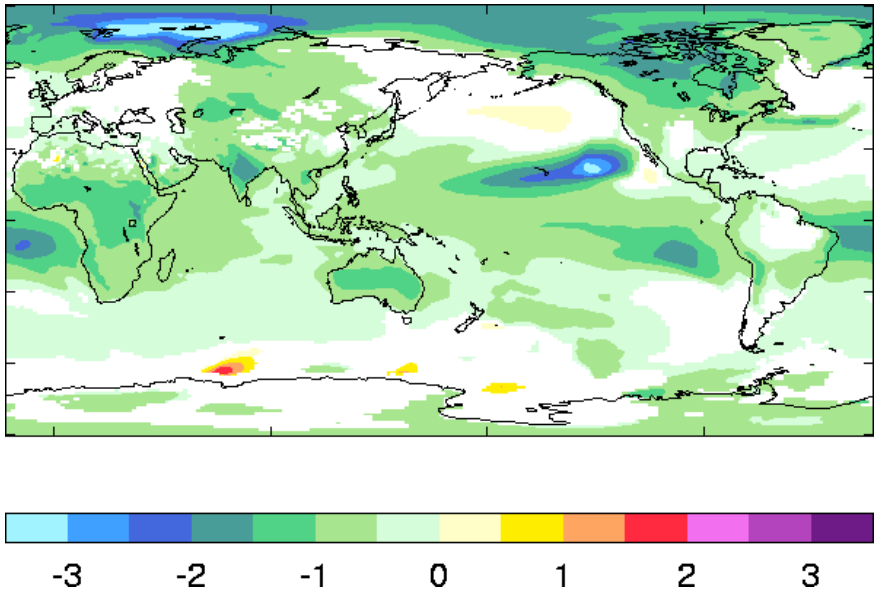
- **UKCA-MODE**

  Mechanistic parameterization being developed at Oxford University: uses information on aerosol number, size and composition of *internally mixed* aerosols.

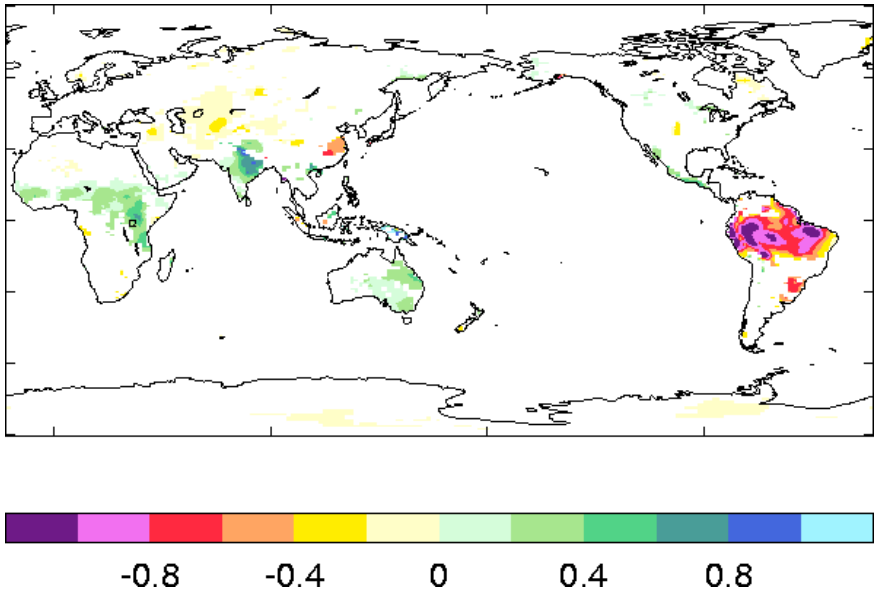
Impact of geoengineered increases of droplet number in the three principal marine stratocumulus regions

(Only changes significant at 5% level shown)

1.5m temperature (K)



Land precip. (mm day^{-1})



Jones *et al*. (2009), *JGR* **114**, D10106